# THE LANDSAT SCIENCE MISSION: TODAY AND TOMORROW

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## ABSTRACT:

The technical innovations of precise numerical radiometry, spectral differentiation and seasonally repetitive monitoring, introduced by the Landsat system, have created a new measurement approach to terrestrial monitoring. The Landsat-7 mission reflects significant progress in realizing the scientific potential of this measurement strategy. Substantial improvements in calibration procedures, both prior to launch and normal operations, have been accomplished to insure long-term stability in the acquired spectral radiometry. For the first time, Landsat-7 will be operated with a long-term acquisition plan that insures, barring national emergencies, that substantially cloud-free, seasonal coverage will be recorded (in the US archives) for all land areas of the globe. In addition, NASA competitively selected a Landsat Science Team, made of representatives from US universities and government agencies to exploit the Landsat-7 record for global change research. This team is addressing the technical and analytical means to process and analyze the core of this observation record, and, for the first time in the history of the Landsat mission, the technical and operational aspects of the mission are being driven by the goals of the US science community. The expected outcome of these efforts is a rapid improvement in understanding the Earth system as well as conceptual knowledge that will underpin commercial application of this technology.

## INTRODUCTION: LANDSAT'S MISSION TO PLANET EARTH

The deployment of Landsat-7 into earth orbit marks a significant evolution in Landsat's more than quarter century mission to monitor the Earth's land areas. Begun in 1972, Landsat pioneered the use of space platforms for systematic collection of land images (Short, 1976). These measurements produced a virtual revolution in terrestrial research, revealing the importance of spectral vegetation index measurements in monitoring biospheric processes and demonstrating the value of tracking the seasonal and interannual evolution of land cover conditions (Kauth, 1976; Tucker, 1979; McDonald, 1980).

The Landsat mission has experienced a variety of stresses over its lifetime. Developed originally by the National Aeronautics and Space Administration (NASA) as an experimental demonstration of capabilities, Landsat never found a comfortable operational home (Marshall, 1989a; Marshall, 1989b; National Research Council, 1995). In 1982, the decision was made to transition the Landsat program to the commercial sector, through the management of the National Oceanic and Atmospheric Administration. A new company, EOSAT, successfully bid to take over operations of Landsats 4 and 5 as well as to produce and operate the follow-on Landsat-6 observatory. Numerous problems were encountered including substantially increased data costs, limited international acquisition activities, and data exchange rights. In 1992, the US Congress voted to return the Landsat mission to Federal government management. Landsat-7 is now operated and maintained under the joint leadership of NASA and the US Geological Survey (USGS) to support both US earth science research goals and the broader applications community.

Much has changed since 1972, when Landsat was the only source of terrestrial observations. Not only have several other nations developed similar observatories (e.g., SPOT, IRS) but also the value and synergy of SAR imaging and lower spatial resolution observations, from systems such as the NOAA Advanced Very High Resolution Radiometer and the French Vegetation instrument, have become widely exploited. Perhaps most important has been the definition of "Global Change" and "Earth System Science" research programs nationally and internationally (IGBP, 1992; Bretherton, 1988; National Research Council, 1993). The technical and scientific advances in monitoring the Earth's land areas from satellites, combined with increasing concerns with potential changes in the Earth's environmental systems, have produced much broader-based scientific interest in the continuity of Landsat-type measurements. Landsat-type observations fill an important niche between the highly repetitive but coarse spatial resolution global observatories and the ultra-high spatial resolution, local imagers planned by commercial operators. Landsat provides systematic global coverage at a repeat frequency sufficient to capture seasonal variations and at a spatial resolution where specific land cover dynamics, under the influence of natural processes and human activities, are clearly evident. If indeed, we are to understand the sources of global change and the impact such changes may have on regional environmental systems and local communities, then Landsat-type observations are a fundamental requirement.

With Earth System Science clearly in mind, NASA incorporated Landsat-7 into its Earth Observing System (EOS) plans in 1994. During 1995, the agency solicited proposals to form a Landsat Science Team to oversee science and application interests in the mission. This team was selected and funded in 1996. These activities reflected NASA's renewed interest in Landsat as a fundamental component of their earth science goals. In keeping with this interest, several aspects of the Landsat-7 mission were given particular attention, to insure that this observatory would strongly support its new EOS role as well as to better serve the broader applications community. Specific items given focussed attention by the NASA Landsat Project Science Office, NASA Goddard Space Flight Center, included instrument characterization and calibration, the development of an Image Assessment System (IAS), and the development of an automated Long Term Acquisition Plan, to insure that a US archive of calibrated, global observations are compiled on an annual basis. These activities have been periodically reviewed by the Landsat Science Team to insure that the mission will meet the EOS requirements. This is the first time in the history of the Landsat program when such a focussed interchange between the NASA managers and the US science community has been undertaken. These activities have laid the groundwork for another revolution in the use of Landsat imagery to study the Earth.

Recent efforts by NASA to solicit concepts for 21$^{st}$ century earth science missions have revealed strong support for continuation of the Landsat mission. Among the several missions that were proposed under NASA's Request for Information on future activities, a Landsat-type follow-on mission received high priority from the earth science community. Anticipating such interest, NASA has pursued advanced technological developments in this area under the New Millennium program. The Earth Orbiter-1 (EO-1) mission, to be launched in December 1999, is dedicated to testing advanced sensors and related hardware for possible deployment in future mission. In addition, active consideration of the mission configuration for a Landsat-type follow-on mission, for deployment in the 2005 time period, is now underway. The pathways to achieve effective Landsat continuity in the early decades of the 21$^{st}$ century are being given careful attention. There is no question that the lessons learned from the Landsat-7 mission will strongly influence these next-generation sensor systems.

## LANDSAT TODAY: THE LANDSAT-7 SCIENCE MISSION

### The Landsat Science Team

<u>Landsat Science and the Role of the Science Team:</u> At its heart the Landsat-7 mission seeks to unravel the linkages which govern the distribution of Earth's landcover, and the variability of that landcover in both space and time. Landcover, in the broadest sense, encompasses virtually all elements of the terrestrial environment, including forests, deserts, farmland, cities, and ice-caps. These elements interact with both the climate system (through exchanges of energy, trace gases, and moisture) and the socioeconomic system by which humans make their living. While coarse resolution, daily measurements from AVHRR and MODIS provide an excellent means of identifying which areas on the globe are changing, they cannot capture the entire dynamics of the land environment because they lack the resolution to determine what on the ground is changing (and therefore why it might be changing). In this context, Landsat makes an ideal fit with the needs of high-resolution terrestrial monitoring. The 30-meter spatial resolution in the VNIR-SWIR spectral range allows Landsat to image fine-scale landcover heterogeneity and

land-use patterns. Furthermore, the 16-day refresh period allows Landsat to capture the seasonal (phenological) cycle for vegetation nearly everywhere on the planet.

The diversity of terrestrial research is well represented on the Landsat Science Team (Table 1). Since 1996 this team has pursued development of methods to improve application of Landsat observations to Earth System Science, through experiments with current and historical Landsat 4 and 5 imagery. The team members have also served as advisors and reviewers to Landsat Project staff in preparation for the launch of Landsat-7. During semi-annual team meetings, NASA Landsat engineers and scientists have briefed the team members on various aspects of the system developments, including sensor radiometry, mission operations and data archival methods being developed for the USGS EROS Data Center. These interactions have resulted in rapid progress to successful implementation, including serious consideration of inter-agency management plans and the design of the Landsat-7 Long Term Acquisition Plan.

The proposed Landsat Science Team REALM concept. As the team has matured, increasing attention has been drawn to how to successfully exploit the exceptionally large volumes of data which are to be collected by the Landsat-7 mission. The US archive alone will accumulate the equivalent of over 90,000 Landsat scenes each year. Fully characterizing land cover dynamics around the globe requires analyzing a major part of this 50-terabyte archive, a technical and scientific challenge not previously confronted during the mission. To address this apparently overwhelming prospect, the Team has proposed development of Landsat Team data processing facility entitled Research Environment for Advanced Landsat Monitoring (REALM). The Landsat Science Team consortium would operate this facility to achieve large area, high volume science queries from the Landsat-7 observation record. The technical configuration of the facility would take advantage of existing advanced computer methods including multi-processor, parallel processing clusters and multi-stage secondary and tertiary data handling.

The scientific challenge for the Landsat Science Team with REALM is to resolve the basic image pre-processing issues that currently block substantial progress in Landsat applications today. These include;

- Precision geographic registration to ± 30 meters
- Multi-temporal scene registration to ± 60 meters
- Identification of clouds and cloud shadows
- Adjustment of spectral radiances for atmospheric attenuation
- Scene to scene radiometric stability

The goal of the REALM pre-processing stream is to achieve, as much as possible, an observation set which represents the true geography and radiometry of land surface spectral reflectance dynamics. Only once these pre-processing methods are well defined will it be possible to develop analytical methods for large

**Table 1**
**Landsat Science Team Member Interests**

| Principal Investigator | Institution | Technical Interests | Applications Interests |
|---|---|---|---|
| Robert Bindschadler | NASA/GSFC | Geometric Registration | Ice Sheet Dynamics |
| Robert Cahalan | NASA/GSFC | Atmospheric Correction, Cloud Detection | Cloud Physics and Scaling |
| Alex Goetz | University of Colorado | Radiometry, Atmospheric Correction | Great Plains Land Cover Dynamics |
| Frank Palluconi | Jet Propulsion Lab | Thermal Infrared Calibration, Integration with EOS ASTER instrument | Environmental Monitoring |
| Susan Moran | USDA Arizona | Atmospheric correction, Integration with SAR | Irrigated Agriculture and Arid Lands Dynamics |
| John Schott | U. Rochester | Radiometry, Thermal Infrared Calibration | Great Lakes Dynamics and Water Quality |
| John Price | Retired (USDA) | Spectrometry, Integration with MODIS | Land Cover Dynamics |
| Samuel N. Goward TEAM LEADER | University of Maryland, College Park | Large volume data handling, Image preprocessing, | Land Cover Dynamics, Detection of Human Activities |
| Kurt Thome | University of Arizona | Radiometric Calibration, Atmospheric Attenuation, Integration with ASTER, MISR and MODIS | Temporal Stability of Measurements |
| James Vogelman | Raytheon STX, EROS Data Center | Radiometric Preprocessing and Error Correction | Land Cover Dynamics |
| Curtis Woodcock | Boston University | Geometric Registration, Radiometry | Forest Dynamics and Conditions |
| David Skole | Michigan State University | Large volume data handling | Tropical Forest Dynamics, Human Activities |
| Frank Muller-Karger | University of Tampa | Radiometry | Coastal and Near-shore Environments |
| Luke Flynn | University of Hawaii | Thermal and Shortwave Infrared Radiometry, Integration with MODIS | Volcano and Fire Monitoring |

area, multi-temporal science queries of the Landsat observation record. The combined expertise of the Landsat Science Team offers access to the best existing methodologies in all of these areas. With the support of NASA considerable progress in developing this critical pre-processing environment for Landsat-7 is possible. Indeed the knowledge gained in implementing the Landsat-7 REALM should produce valuable knowledge to guide the design of future missions that continue the Landsat heritage.

**The Landsat Project Science Office**

The activities of the Landsat Project Science Office (LPSO) at NASA Goddard Space Flight Center over the last several years have been critical to the successful deployment of Landsat-7 as a NASA EOS observatory. The specific challenges presented to this group of NASA scientists included improved sensor radiometry and stability, development of an operational mission assessment system and definition of the Long Term Acquisition Plan for daily Landsat operations to support population of the US-held archive at the USGS EROS Data Center. All of these activities were focussed on insuring that Landsat-7 observations would achieve the NASA earth science goals posed by the US Global Change Research Program and the Earth system science strategy.

<u>Sensor calibration and stability</u>. The data from land remote sensing systems such as the ETM+ cannot easily be compared and integrated for the detection, monitoring and characterization of global change without calibration

to common units of measurement. Calibration is essential to the role of Landsat 7 in the Earth Observing System (EOS) era. The inclusion of a new full-aperture-solar-calibrator (FAC) and a partial-aperture-solar-calibrator (PAC) on Landsat 7 will afford improved calibration relative to the earlier Thematic Mapper and Multi-Spectral Scanner sensors on Landsats 4 and 5. The FAC and PAC devices will permit use of the Sun, with its known exo-atmospheric irradiance, as an absolute radiometric calibration source. The data provided by the on-board solar calibrators, in conjunction with an internal calibration lamp and occasional ground-based validation experiments, will permit calibration to an uncertainty of less than five percent. This level of accuracy is consistent with the radiometric requirements for other EOS era sensors.

The Landsat-7 ETM+ instrument has completed its pre-launch calibration and characterization testing, though derivation of final instrument calibration parameters is ongoing at this date. In most respects the ETM+ has shown comparable or better performance than the Landsat-4 and 5 TM sensors. System spectral response, based on component level measurements, is similar to previous TM instruments. One notable, positive difference is in band 5, where the ETM+ response cuts off near the nominal value of 1. 75 μm vs. the 1.78 μm of Landsat 4 and 5 TM's, thus providing a bandpass freer of atmospheric absorption. ETM+ noise levels are predominantly at or better than specification values. Radiometric calibration of the ETM+ using a large aperture integrating sphere was performed in ambient environmental conditions and has demonstrated excellent ETM+ linearity. The precision of this ground-based radiometric calibration of the ETM+ was performed to better than the 0.1%. ETM+ stability in ambient conditions over 18 months of testing has shown responsivity stability at the ±1% level. Spatial performance, in terms of modulation transfer function, has been within specification during pre-launch testing and is expected to remain within specification on orbit for all bands, with the exception of the panchromatic band. In the pan band, pre-launch and initial on-orbit performance is expected to be within specification, but over the life of the mission the focus is expected to shift, bringing the pan band out of specification. By end of life the panchromatic band is expected to have roughly 20 meter performance.

Image Assessment System (IAS). In addition to the improved calibration of the ETM+ instrument, it should be noted that the Landsat 7 ground system design includes an Image Assessment System (IAS) component to provide the ancillary information needed to generate radiometrically calibrated, geometrically corrected ETM+ digital imagery. The Landsat Project Science Office at NASA/Goddard oversaw the development of the IAS (Irons et al., 1995) in conjunction with personnel at EDC. The IAS will assess ETM+ data quality and calibrate the sensor radiometry and geometry. The information provided by the IAS will facilitate the production of digital image data with an absolute radiometric accuracy of five percent, band-to-band registration of 0.3 pixels, and geodetic registration to 250 m ($1\sigma$) without ground control.

Long Term Acquisition Plan (LTAP). Through the effort of LPSO staff, the Landsat-7 mission operations, for the first time, are designed to accumulate annually, a global, seasonally refreshed, substantially cloud-free, US-held archive of observations. The USGS Earth Resources Observation Center (EROS) Data Center, Sioux Falls, South Dakota will be the repository for this archive. The US global archive is capable of accepting 250 scenes/day (>90,000 scenes per year). Acquisitions for the US archive will be selected by an automated Long Term Acquisition Plan. The NASA Landsat Project Science Office, at the Goddard Space Flight Center, developed this plan in cooperation with members of the NASA Landsat Science Team. The LTAP attempts to optimize the quality of acquisitions through consideration of land seasonal dynamics, as revealed in NOAA AVHRR observations, and a comparison of NOAA forecasted cloud conditions relative to International Satellite Cloud Climatology Project nominal cloud conditions (Goward, 1996).

Landsat 7 operations are configured to acquire all scenes in the United States, including Alaska and Hawaii. For other regions of the globe, observations are concentrated in vegetation growing seasons with reduced acquisitions during dormant periods and for major deserts and ice sheets. Once every 24 hours cloudcover forecasts are acquired from the National Oceanic and Atmospheric Administration. These forecasts are compared to the local cloudcover climatology to determine next day acquisition priorities from among all the scenes specified for possible acquisition that day, which is, on average, about 400 scenes. Pre-launch tests of the LTAP using historical cloudcover data produced complete global coverage within one year and reduced cloud contamination within acquired scenes (Fig 1). In addition to the US acquisitions, as many as 18-20 international ground stations are expected to sign agreements with NASA and USGS to receive direct broadcast of observations for their acquisition regions. This combination of systematic US global acquisitions and high volume international collections will provide a rich new source of earth information for scientific research and applications.

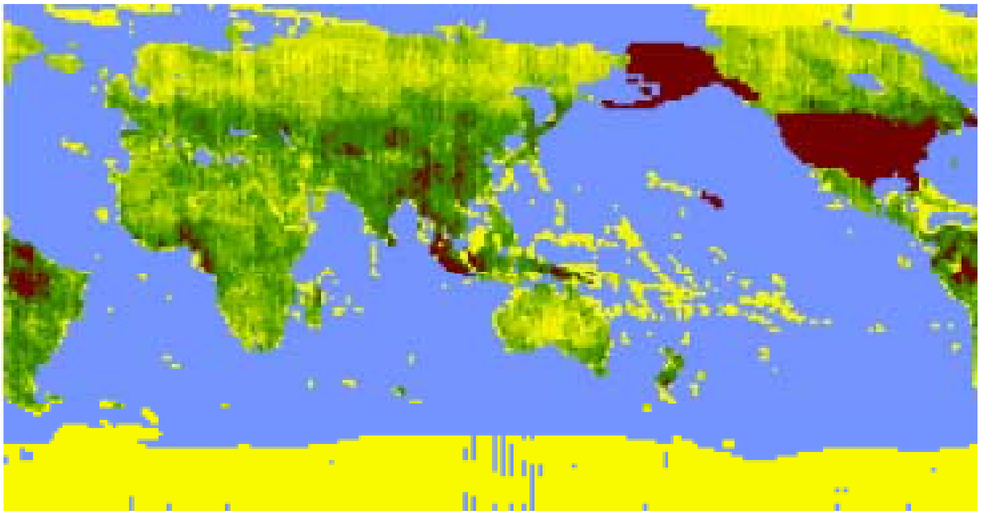

Fig. 1: Simulated acquisition pattern for one year of Landsat-7 operations, using the Long-term Acquisition Plan (LTAP). The LTAP takes into account cloud-cover, seasonal vegetation patterns, and instrument gain changes to maximize acquisitions that characterize land cover changes around the globe. Dark red regions (including the United States) are acquired on every overpass (22 acquisitions/year), while yellow areas are acquired at least once each year.

The combined impact of the LPSO activities is a mission configuration of Landsat-7 far in advance of previous deployments in this long term land monitoring program. These efforts represent the maturation of the land science community's understanding of what is needed to accomplish accurate and timely assessment of land cover dynamics. Indeed, absence of the LPSO efforts would have seriously hindered the Landsat Science Team's current efforts to pursue the REALM concept.

## LANDSAT TOMORROW: THE EO-1 AND EOS-1 MISSIONS

There is no question that the terrestrial remote sensing community has, over the last quarter century, become accustomed to readily available Landsat-type observations. Even through the difficult "EOSAT" era considerable interest was maintained in the data. Indeed, at the moment, requests for historical Landsat digital imagery are at an all time high at the USGS EROS Data Center, with more that 50 Landsat scenes ordered by interested users each day. The intensive coverage and reduced costs of Landsat-7 observations no doubt will substantially increase this demand, with 250 scenes being added to the EROS archive each day (as well as the international ground station receptions). The era of true global Landsat monitoring has arrived. For any interested researcher or applications specialist, observations for their area of interest should be readily and plentifully available. This achievement of Landsat's true technological and scientific potential is upon us, albeit a bit delayed by the confusion and conflicts surrounding the evolution of this nascent terrestrial observatory.

The sustained earth science interest in continuing these observations is reflected in two NASA supported activities, the EO-1 mission and the EOS-1 concept. In both cases these activities grew out of the expressed interests of terrestrial researchers to pursue advanced concepts for continued Landsat-type monitoring of the Earth in the 21st century. To say that the optical-mechanical sensor design on Landsat-7 is out-of-date is to be kind. This design was first proposed in the mid-1960's when the concepts of integrated circuits and solid-state sensors were primarily laboratory experiments. Under normal technical conditions the design used in Landsat 4 and 5 would have been replaced with lower cost and more capable sensors on both Landsats 6 and 7. Unfortunately the chilling effects of premature, mandated commercialization froze sensor technology in the 1960s time frame. Thus, it is no surprise that under NASA's New Millennium technology demonstration program, rapid progress has been achieved in developing a true "faster, cheaper, better" approach to Landsat-type observations. The EO-1 satellite is planned for launch in late-1999 and will be placed in a formation orbit with Landsat-7, permitting it to view the same locations approximately 1 minute later than Landsat-7.

**The EO-1 Mission**

There are three experimental sensors on board EO-1: the Advanced Land Imager (ALI), an atmospheric profiler and the Hyperion hyperspectral imager. One of the early lessons learned during the EO-1 design development is that current hyperspectral sensor designs are not well suited to produce the 30 m, 185 km swath observations expected from a Landsat-type system. It is likely that over the next several years current fabrication problems will be resolved, warranting continued exploration of this sensor approach. The Hyperion sensor will serve as the test bed to examine some of the future potential of spacebourne hyperspectral measurements for landcover applications.

The Advanced Land Imager is a broad band (Landsat-type) solid state sensor which produces radiometric measurements with better than 4 times the signal to noise as the Landsat-7 ETM+, but with a package which is more than 7 times smaller than the ETM+. Laboratory tests of the ALI sensor indicate that approach to Landsat-type sensor technology is a substantial advance in every dimension of faster, cheaper, better. Since the EO-1 is a technology test bed, only a limited portion (≈ 36 km ground swath) of the full focal plane is populated with sensors. Nevertheless, the near-coincident availability of sample EO-1 and Landsat-7 ETM+ measurements should quickly demonstrate the value of this advanced approach to collecting the required measurements. The only immediate concern is that the ALI the focal plane is not capable of sustaining cooled thermal infrared sensors. It does appear, however, that there are near-term solutions to provide the TIR capability.

The atmospheric profiler is a 250 m spatial resolution hyperspectral sensor designed to characterize atmospheric attenuation by water vapor and aerosols. It is optimized to extract the water vapor content and aerosols composition of the atmosphere between the satellite and the ground. This experiment is directed to resolving the problem of variable atmospheric attenuation from the Landsat analysis stream. Research to date suggests that such an approach is essential if this unwanted variable is to be removed from the analytical environment (Kaufman, 1988; Tanré, 1992). Measurements from this system, when recorded, will be available for the full 183 km swath of Landsat-7.

Of additional note is the planned near-coincident orbit of the EOS Terra (AM-1) mission to both Landsat-7 and EO-1. It is anticipated that Terra will be placed in an orbit approximately 30 minutes behind Landsat-7. This means that the observations from the MODIS, the MISR , and the ASTER instruments (Asrar, 1993) will also be available for comparison and combination with Landsat-7.

There is no question that the next 5 years will be some of the most scientifically and technically interesting and challenging periods in the evolution of terrestrial remote sensing. The various anticipated and unanticipated synergies between this complex array of near-coincident sensors will produce knowledge to substantially advance terrestrial remote sensing for decades to come.

**The EOS-1 Concept**

While the current generation of sensor systems is being placed into orbit, consideration of the next generation of Earth observation missions is now underway. In 1998 NASA Headquarters released a Request for Information, soliciting proposal for the next generation of Earth observation missions. In the land community numerous proposals were put forward, including our own for a “Landsat Next” mission. Through a multi-stage process scientific peer-review panels have considered the full range of proposals. At each stage, the concept of a follow-on Landsat-type mission received strong support. Currently, the specifics of the configuration and context for this mission are being refined and reviewed to produce a plan for new activities in the 2005 time frame.

At the moment this proposed activity is entitled “EOS-1 Land Cover/Land Use Inventory”. One of the critical elements in this proposal is that it must be an end-to-end concept, which rapidly resolves pressing science issues in global change. The natural fit for this activity is tracking the dynamics of land cover. Indeed the science theme is “long-term monitoring of global land cover/land use dynamics based on a systematic annual assessment of land cover change”. This sounds simple enough, but it poses serious technical and scientific challenges unresolved in previous Landsat missions. In fact, it calls for resolution of most, if not all, the problems encountered in Landsat-based terrestrial monitoring today.

Many of the basic challenges being addressed by the Landsat Science Team today, may have technical solutions within the hardware and software of future missions, rather than passing these problems on the data end users. For example, if the atmospheric profiler on EO-1 provides a means to effectively characterize variable atmospheric attenuation, it resolves a problem which as of yet has found no solution in post-processing of currently acquired imagery. This issues include:

- Cloud and cloud shadow detection
- Variable atmospheric attenuation
- Radiometric precision
- Stability of radiometric calibration
- Spectral consistency
- Navigational accuracy
- Geographic repeatability

In each case, technical solutions may be possible which eliminate these factors from interpretation of the imagery. If careful attention is paid to these problems, in the design and development of sensor systems and platforms, this will go a long way toward advancing the immediate scientific and practical applications of these data.

Of further concern is the assurance that such data will be rigorously subjected to the type of intensive analysis which produces timely, annual assessments of global land cover dynamics. Current national and international activities such as the international Global Observation of Forest Change (GOFC) program and the US EPA/USGS North American Landscape Characterization (NALC) represent prototypes of the more comprehensive end-to-end mission potential for EOS-1. Following the example of the Astronomical community, it now appears to be appropriate to form a consortium of US and international terrestrial scientists focussed on resolving the land element in global change and Earth system science research. Perhaps the current Landsat Science Team activities surrounding the REALM concept can serve as a model of how this might be accomplished. Planning for such a broad-based terrestrial consortium is a fundamental component of the EOS-1 concept.

Another interesting aspect of the EOS-1 proposal, is the potential role the US commercial remote sensing community. Already, one company, Resource-21, has expressed strong interest in deploying a compliment of 4 Landsat-type sensors simultaneously, selling a portion of this data back to the US government to meet their needs. The four satellites are to provide near weekly coverage of important phenological events, particularly for agricultural applications. Unfortunately, this company's progress in realizing this dream has been slow. No doubt for the same reason scientific progress has been slow with Landsat, the business managers in this company may find overcoming the immediate data handling and preprocessing issues as a daunting task. It may well be that the time is ripe for the land science and commercial communities to come together to push this technology to its fullest. A satellite constellation of 4 or more Landsat-type sensors is strongly appealing to all members of the terrestrial research and applications communities. Perhaps a joint venture, splitting the costs between US taxpayers and US investors is just the push the community needs.

## CONCLUSIONS: LANDSAT FOREVER?

Up to this point, our discussion has revolved around nothing but Landsat. No doubt, as we age this type of consistency and continuity become more appealing. However, technical and scientific progress conspire against our desire for stability. This first quarter century of electronic imaging of the Earth from space has been exceptionally exciting and stimulating. To see such a new approach to better understanding our planet evolve within one's professional career is all one could ask for. However, to believe that we have reached an ideal technical plateau is simply myopic. With evolving computational power and sensor technologies, a look back on our current efforts will seem primitive. Information from sophisticated fine band (better than hyperspectral) sensors no doubt will be subjected to on board processing, and telemetering all of the information needed "right now" to make decisions "today" will be the norm. Many novel configurations of satellites and sensors will work together to address specific science and applications questions.

With Landsat we only began the process of studying the Earth from space. As Archimedes was quoted, when speaking of the lever, "give me a place to stand on and I will move the Earth". So satellite remote sensing has moved and advanced our understanding of this planet to an entirely new level. However we have only begun to explore the potential. Is Landsat forever? Regardless of the answer, its heritage will certainly move future generations.

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